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Bitcoin is a relatively new and attractive asset. It is used for peer-to-peer transactions and is built upon an interesting system called the Blockchain which allows for fast and secure transactions between users. Although Bitcoin and its underlying infrastructure show a lot of potential for growth and innovation, many users of the so-called "cryptocurrency" are wary of holding it instead of other currencies such as the U.S. dollar because of the high volatility exhibited in the price of Bitcoin.

The goal of this paper is to examine the use of theoretically priced put options, "protective puts", to hedge against price decreases that Bitcoin may experience. The user of this protective put strategy is considered to be an investor with an optimistic view on the price of Bitcoin and wants to own some, but is uncomfortable with the potential for substantial losses due to price decreases. In implementing the protective put strategy, the price of Bitcoin that the investor owns has a floor at the strike price of the options purchased to hedge the risk of price decreases. If the price increases enough, then the options are sold, and those with the new strike price are bought to lock in a higher protected price for the investor. The investor's goals are to reduce the risk of losses by owning Bitcoin while its price decreases and to lessen the volatility that his portfolio experiences at the expense of the cost of purchased options eating into potential profits.

Upon analysis of both historical and simulated data, utilizing protective puts as a hedging mechanism against decreases in the price of Bitcoin has proven effective at reducing expected volatility and limiting losses. The use of the strategy, when analyzed across different simulated market environments, allows for the capture of price increases while stopping excessive losses. Proportional to an unhedged Bitcoin portfolio, the proposed approach reduces volatility more than it reduces expected percentage gains. Upon analysis, the expected profit is slightly less than 28% lower at around 8% hedged from 11% unhedged. However, the standard deviation of percentages of profits or losses is 53% lower, having decreased from 27.8% to about 13.1%.

BITCOIN: A BRIEF INTRODUCTION

HISTORY, MECHANICS AND USE OF BITCOIN

In October of 2008, a mysterious person or group known as Satoshi Nakamoto released a paper detailing a peer-to-peer electronic cash system that would come to be known as Bitcoin (The New York Times 2013). The software behind Bitcoin, called the Blockchain, was innovative because the code allowed transactions to be authenticated and processed without a central bank or government. For years, Bitcoin grew nearly unbeknownst to the mainstream public as it was used mostly to facilitate black market transactions. In April 2013 a price surge in the value of Bitcoin caused the total value of all bitcoins to surpass one billion US dollars–this milestone triggered a media frenzy.

Over the past 30 months, the value of a single Bitcoin has continued to be volatile, reaching a peak of over $1,242 US dollars before descending to the current price of around $430 per bitcoin (Coindesk 2015). During this period Bitcoin has been adopted as an accepted form of payment, and notable companies have implemented payments using it including Microsoft and Overstock.com (BitcoinValues 2015). Governments have demonstrated an interest in understanding and regulating Bitcoin. For example, former US Federal Reserve Chairman Ben Bernanke has said that Bitcoin "may hold long-term promise, particularly if the innovations to promote a faster, more secure, and more efficient payment system" (Tracy 2013). Bernanke highlights three key advantages that Bitcoin holds over traditional currencies. Bitcoin transactions theoretically are more secure, faster, and effectively free to facilitate. Not all governments have welcomed the rise of Bitcoin, China's central bank has prohibited any financial institutions from handling bitcoin transactions (Wilhelm 2014).

Bitcoin has attracted speculative investors who seek to capitalize on its volatility and perceived upside. As Bitcoin has become more established as a potential asset, companies have recently begun facilitating the development of Bitcoin options exchanges.

ISSUES HOLDING BITCOIN BACK FROM MAJOR ADOPTION

Despite the potential that Bitcoin has, many issues hold it back from large-scale adoption. Legality and security are the first two problems that potential investors run into when considering Bitcoin as an investment. These two issues are very gray at the moment, as some countries consider Bitcoin to be a currency while others consider it property and potential gains or losses are taxed differently. Many investors can buy Bitcoin online and hold it in a 3rd party wallet, but most do not have the deep understanding of computer science and cryptography that underlies Bitcoin. Additionally, news of stolen Bitcoin and unknowns about flaws or holes in storage mechanisms can also scare away buyers (Onies, Olayinka, Daniele).

Despite these issues, Bitcoin has seen adoption because of its use in payments and also because of the potential that its Blockchain architecture holds for future development. Finally, should an optimistic or informed buyer decide to purchase bitcoins, they should expect the price of the cryptocurrency to be highly volatile. One bitcoin is one bitcoin; however, most people operate under a system where their base currency denomination is not in Bitcoin. The volatility shown in exchange rates is often due to news about acceptance or governmental regulation, in addition to market factors and broader adoption of the technology. The result of this volatility is that should an investor want to redeem his bitcoins for another currency, he may receive much more or much less than was originally spent to acquire them.

BITCOIN AS AN INVESTMENT

Because of the extraordinary potential that Bitcoin and the Blockchain have shown in recent years, there has been demand for the digital currency as an alternative investment. While reasons for owning it may differ, ranging from holding a different currency, the potential for capital appreciation or to be part of the future, the desire is there. However, there are few people willing to take on the risk of owning bitcoins when the price of the asset is so volatile concerning its exchange rate into US dollars. The Bitcoin market is still nascent and as such proper hedging methods have not been developed yet, requiring investors to accept the risk present in the market. Bitcoin adoption may be much higher in the future if people can have more control over the financial outcomes of their investment through hedging mechanisms (Prior 2015).

HEDGING A HISTORICAL BITCOIN PORTFOLIO

METHODOLOGY AND GOALS

To test hedging the risk of a buy-and-hold Bitcoin portfolio, the decision was made to use the simple, yet often effective strategy of buying protective put options (CBOE). To evaluate how well the strategy would have worked, the last six months of daily price data for Bitcoin as a test sample. For the put options, European-style options were used, and the strike prices were set at $25.00 intervals. The expiry was placed to be at the end of the six-month period tested. Ten put options were bought (each covering 100 bitcoin) on the first day, as well as 1,000 bitcoins and progress of the hedge was tracked over the six-month period. The purchase of the put options is assumed to have been funded from a pool of cash which can be accessed for the cost of options and it is not tracked separately from the rest of the portfolio, although gain and loss from sales and purchases of puts are. To capture the upside of the investment in Bitcoin, if the price moved high enough to warrant the purchase of a put option at a higher strike price, it was done so. In doing this, the old put was sold to regain some of the cash spent on it because it is no longer required for the hedge. If the price of Bitcoin dropped below the strike price of the options, the price was locked-in at the strike price. The options were held until expiry since they are European-style and cannot be exercised beforehand. This allowed the price of Bitcoin to move until the expiry of the hedge and to possibly not require the use of the put by the time the option's expiry date arrived.

The goal of implementing such a hedging strategy is to reduce the volatility the Bitcoin portfolio experiences and to limit losses, while not sacrificing a majority of upside potential. Due to the high historical volatility of bitcoins, it was sought to determine whether a hedging strategy involving protective put options will limit losses while still allowing for significant upside for the long-term investor who is optimistic about Bitcoin prices and adoption.

SIMULATING OPTIONS PRICES

In order to price the options for the protective put strategy, the Black-Scholes equation was used (Black, Scholes 1973). In order to compute accurate prices for the puts, the following inputs were used:

- Risk-free interest rate of 1.00%
- Daily price of a bitcoin
- Strike price in increments of $25.00
- Days remaining until option expiry
- Dividend of zero
- Historical volatility of Bitcoin prices, calculated to be 53.40%

Put prices were calculated using these inputs by a Visual Basic for Applications (VBA) script inside an Excel sheet, as well as in a column-based format for consistency and compatibility with Palisade Corporation's Excel add-in for simulation, *@Risk*. To calculate the volatility to use in the equation, the historical percentage of Bitcoin price changes over the six-month period the experiment was run on was used. To get the yearly volatility, the standard deviation of those values was multiplied by $\sqrt{365}$, because Bitcoin trades every day of the year.

ASSUMPTIONS MADE DURING MODEL DEVELOPMENT

To streamline model development and simplify the analysis, some theoretical assumptions were made. One major assumption is that there are no transaction costs. Many Bitcoin exchanges charge a fee for placing trades, typically 0.25% of a transaction's face value Coinbase. Additionally, Bitcoin options exchanges are not up and running yet, so transaction costs for options were omitted as well due to a lack of data and desire for simplicity in determining the efficacy of the protective put hedging strategy.

Bitcoin, being considered an alternative currency, is purchased by exchanging another form of currency for it. In the historical scenario and simulations run, Bitcoin is bought with U.S. dollars; however, no currency exchange fees are incorporated, nor are bid or ask spreads. Some exchanges charge a final fee when Bitcoin is converted to another currency or withdrawn from the account. These costs were not built into the model since the premise of this work is based on an optimistic Bitcoin investor who has no desire to withdraw any form of currency from his accounts.

Lastly, the options market for U.S. equities will sometimes exhibit mismatched prices or market making spreads. This model assumes that option prices will not be affected by these factors and that they will trade at their fair value as determined by the Black-Scholes equation with inputs specified above. There will be no market impact as liquidity is assumed to be infinite, and there will be no transaction costs per contract or order.

ANALYSIS OF HISTORICAL RESULTS

PERFORMANCE OF PUTS OVER SIX-MONTH TEST PERIOD

Over the six-month test period evaluated, the protective put strategy worked well. The value of Bitcoin during the evaluation period was relatively volatile, which provided a good scenario for the procedure to be tested against. The price of a bitcoin over the six months chosen can be seen in Figure 1. The price path looks as though it follows a rough sine wave with a five-month wavelength and then spikes up during the sixth month. This study's goals are to limit the downside of an investment in Bitcoin while retaining most of the upside and reducing the volatility of returns. Regarding accomplishing these, the protective puts worked as planned.

During the six-month period, a few different trends seemed apparent based on the price path. During the upwards part of the wave in the price of a bitcoin, the portfolio increased in value, and the downward drag on value was the cost of upgrading puts to their next strike price. This impediment to the portfolio's value is to be expected, as a hedge can be defined as paying a price to reduce uncertainty. When the price went down below that of the strike price of the options owned, the lowest price for the portfolio was capped at the strike price of the options, multiplied by the number of bitcoin owned plus the cost of the options. In this section of time, the options did not expire, allowing the right to sell the bitcoins in the portfolio for a set price moving forward if the portfolio needed to be liquidated. The portfolio remained intact, and the price of bitcoin moved upwards again, allowing puts of an even higher price to be purchased and lock in a higher price for each bitcoin. On the last day, since the price of bitcoin was above the strike price of the puts owned, the puts expired worthless.

The effects of the hedge can be seen in Figure 2, where the cost of the portfolio was locked in near the beginning, only increasing when puts were exchanged for others at a higher strike price. The value, however, increased over time and did not have the ability to fall much below the original cost of the portfolio in the worst case scenario of the price of Bitcoin falling through the strike price of the puts. In Figure 3, it can be seen that the volatility of the hedged portfolio is much lower, and the potential for loss was much lower. When compared to the unhedged portfolio's profit and loss, it is clear that without hedging, selling any time from months three to five would have resulted in a loss, while the hedged portfolio would have allowed the capture of approximately a 20% gain.

Reducing the volatility of the portfolio was another goal when using the protective put strategy. Using the historical volatility model to get the volatility for Bitcoin over the six-month period gave a 53.4% yearly volatility. Using the same metrics for the percent changes in the value of the portfolio comprised of Bitcoin and put options, the volatility resulted in a value of 39%. Evaluating solely the volatility of the 1,000 bitcoins owned in the portfolio gave the same result, offering a 39% yearly volatility. As such, the puts did effectively reduce portfolio volatility over the six-month period, while allowing the capture of upside and potentially limiting losses should the price of Bitcoin decreased over the time period examined.

SIMULATION OF BITCOIN PORTFOLIO USING RANDOM WALKS

METHODOLOGY

To get a better idea of how the protective put strategy would work in different and potentially trending environments, simulated geometric random walks were used to analyze potential price paths of Bitcoin over a period of six months (Nau). 10,000 simulations were run for each random walk scenario and the portfolio and Bitcoin profits and losses in dollars and percentages were analyzed as outputs, as well as portfolio and Bitcoin volatility. Initially, a positive drift was used in the random walk, indicating a general uptrend in the simulated price of Bitcoin. To validate the strategy in multiple types of markets, random walks with negative and null drift were also used.

RANDOM WALK WITH POSITIVE DRIFT

In order to simulate the price of Bitcoin, a geometric random walk with positive drift was initially used. Upon analysis of the natural logarithm of historical price changes represented by $\ln(S_{t+1}/S_t)$, there was a positive drift of value 0.0032 based on the average daily price change percentage with volatility incorporated. Stated symbolically, $(\mu - 0.5\sigma^2)$, where μ is the drift value calculated and σ is the standard deviation of the daily changes, of value 0.02808. It is worth noting that the drift may be different based on different windows of time. The ones digits in the formula used represent the size of the time step for each day, as the equation progresses to price S_{t+1} from S_t daily. The random walk with positive drift is represented by the equation below, where ω represents a random perturbation chosen from the standard normal distribution.

$$S_{t+1} = S_t * e^{(0.0032-0.5*0.02808^2)*1} + 0.02808 * \sqrt{1} * \omega_{t+1}$$

Unsurprisingly, with the positive drift, the simulated price of a bitcoin trended up, resulting in a mean ending portfolio value of $433,000 given a beginning investment of $228,230 (the cost of 1,000 bitcoin at the starting date of the historical scenario). After incorporating the cost of buying and selling options to hedge the simulated positions, the average profit was 34.2% over the simulated term of six months (Figure 4). Over the same period and using the same inputs, the percentage of profit on the unhedged portfolio was 77% (Figure 5). Comparing the profit and loss percentages to those achieved by the unhedged portfolio, the unhedged portfolio has a much greater return. This return is not surprising since the positive drift term in the random walk equation should result in favorable increases in Bitcoin's price over the duration of the simulation, making a hedge less necessary in hindsight.

A comparison of the standard deviations of the scenarios also reveals the effects of hedging. The standard deviation of the profit and loss percentage for the unhedged portfolio is 69% while the protective puts decreased that same profit and loss standard deviation to 34% for the hedged portfolio. It is clear that the protective put strategy allows an investor to invest with less risk by reducing standard deviations of simulated profit and loss percentages, but the strategy also sacrifices potential return, likely due to the high price of the options due to volatility.

RANDOM WALK WITH ZERO DRIFT

While the six-month period analyzed had shown the price of Bitcoin to exhibit an upward trend, this may not be the case in the future. For this reason, random walks of null and negative drift were analyzed as well in order build a better image of what may happen using the protective put strategy in environments of less favorable price paths. The equation used for the random walk with zero drift is:

$$S_{t+1} = S_t * e^{(0.0-0.5*0.02808^2)*1} + 0.02808 * \sqrt{1} * \omega_{t+1}.$$

Simulating the random walks using a drift value of zero provided results representative of approximately an equal number of winning and losing price progressions. The average expected profit for the portfolio comprised of put options and bitcoins was slightly less than 1%, with a standard deviation of 16.7%. Examining the chart (Figure 6), it is clear that the protective put strategy had an effect on the outcomes, there are spikes in the histogram of outcomes representing the price floors that the put options created. This shows that the options did indeed limit the losses that could have been experienced in downward trends. The effect of the options can also be seen in the confidence interval. The hedged portfolio had a 90% chance of ending with an expected profit or loss between -19.3% and 33.4%, while the same confidence interval for the unhedged portfolio expected between a -

49.8% and 72.8% profit or loss.

The unhedged portfolio has a much smoother distribution of outcomes (Figure 7), representing the outcomes of wherever the price of Bitcoin ended during each simulation. The expected loss for the unhedged simulations was approximately zero percent, but with a much higher standard deviation of 39.12%. When comparing the unhedged portfolio to the hedged portfolio, the puts managed to reduce expected losses to about a maximum of 19.3%, while the unhedged portfolio had a 4.9% chance of losing more than half of the initial investment. Expected gains also decreased by over 50%, however this was an expected consequence of the hedging strategy's option costs.

RANDOM WALK WITH NEGATIVE DRIFT

After evaluating random walks with positive and zero drift, for completeness a random walk with negative drift was simulated. For the drift value, -0.0032 was used, since this is the negative counterpart to the positive value used in the random walk with positive drift. When the expected profit is negative, as is the case when the drift implies a downward trend in the simulated price of Bitcoin over time, the benefit of a protective put strategy became most apparent due to limiting losses consistently. The equation used for the random walk with negative drift is as follows:

$$S_{t+1} = S_t * e^{(-0.0032-0.5*0.02808^2)*1} + 0.02808 * \sqrt{1} * \omega_{t+1}.$$

The hedged distribution of profit and loss percentages has some peaks likely representing different strike prices that the options prevented the portfolio from falling under (Figure 8). The mean of the distribution is -11.2%, which is likely attributable to the price of Bitcoin falling to the strike price of the option fairly quickly, but the portfolio was prohibited from dropping any further. The standard deviation of the hedged strategy's results was a mere 7.4%. Because of these factors, the most lost was 19.3%. There was a 90% chance of earning anywhere from the minimum to 3.4%, although the strategy tended to lose approximately either 19%, 14% or 7% due to the strike prices. Also included in the losses are any increases in the simulated price path resulting in a higher strike price before the options were driven into effect.

The unhedged distribution suffered significant losses in the negative drift scenario. Given the bias of the simulated price to trend down, the expected loss was 43.97%, with a standard deviation of 21.98% (Figure 9). In the simulated scenario, there was a 90% probability of losing between 3.9% and 71.9%, with the highest simulated loss being 85.64% although it could theoretically be 100%. When compared to the summary statistics of the hedged portfolio, it is clear that hedging is expected to reduce volatility and expected loss significantly in a situation of negative drift.

COMBINED P&L OF RANDOM WALK SCENARIOS

To verify the usefulness of the protective put hedging strategy in reducing expected losses and volatility over different price paths, a simulation was conducted with all three previous random walks. The results of the distributions of both the hedged and unhedged distributions were simulated 10,000 times. To establish the combined statistics of the hedged and unhedged portfolios, it was assumed that each outcome is equally likely. For comparative purposes, the charts of the hedged and unhedged simulated outcomes are overlaid (Figure 10). Visually, the blue unhedged distribution is much more dispersed, as is confirmed by its standard deviation of 27.83% on a mean of 11.14% profit. Confirming previously simulated outcomes, the red distribution of hedged results has a standard deviation of 13.1% and a mean of 7.99%. Analyzed another way, the combined hedged scenarios have a standard deviation that is 52.9% lower than the combined unhedged scenarios. The expected return of the hedged distribution is 28.3% lower than that of the unhedged distribution. According to the results of the simulation, the use of protective puts reduced the volatility of the profit and loss distribution more than the expected return was reduced, indicating that the strategy worked successfully for the purpose of reducing the volatility of returns, limiting downside and not compromising too much upside.

CONCLUSION

Based on the analysis performed, a hedging strategy utilizing protective put options reduces the volatility and minimizes losses of a Bitcoin portfolio historically. Additionally, when the price of Bitcoin is simulated using geometric random walks, protective puts reduce anticipated losses and volatility over scenarios of expected price increases, decreases, and flat trends. If the value of Bitcoin appreciates significantly, then the cost of the puts options reduces the possible gains, however, less so than the reduction in volatility. Due to the strategy of purchasing puts options at greater strike options in the case of significant appreciation, the bitcoin portfolio locks in a gain. An unhedged Bitcoin portfolio would be completely exposed to a sharp decline in Bitcoin prices that completely wipes out gains or produces significant losses. By the effects of mitigating losses, reducing volatility and still providing a return, the use of a hedging strategy such as the proposed protective put strategy may well be useful for optimistic Bitcoin investors.

APPENDIX

In order to download a zip file containing model files, simulation outputs and other materials related to this paper, **click here** to be directed to Google Drive.

Figure 1: Price path of Bitcoin for the six-month historical test period.

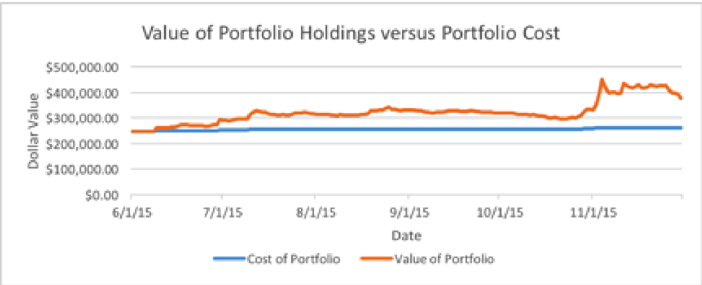

Figure 2: Value of the portfolio versus cost over the same six months.

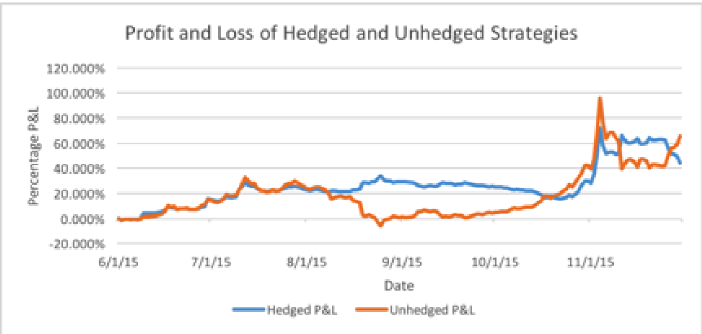

Figure 3: Comparison of profits historically, with and without hedging.

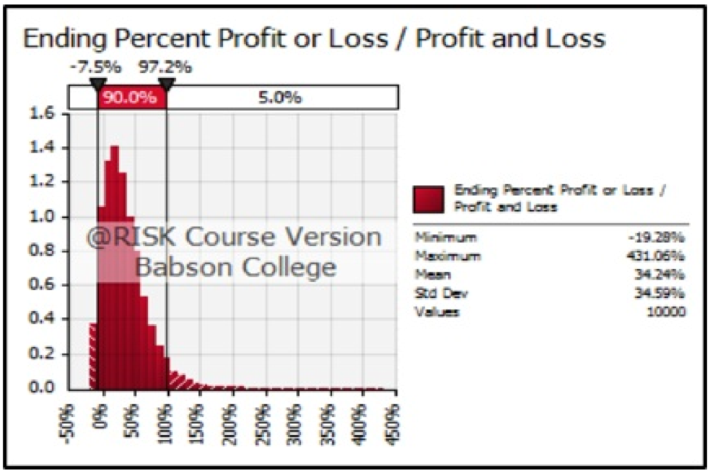

Figure 4: Simulated P&L percentages of strategy with an upward price trend.

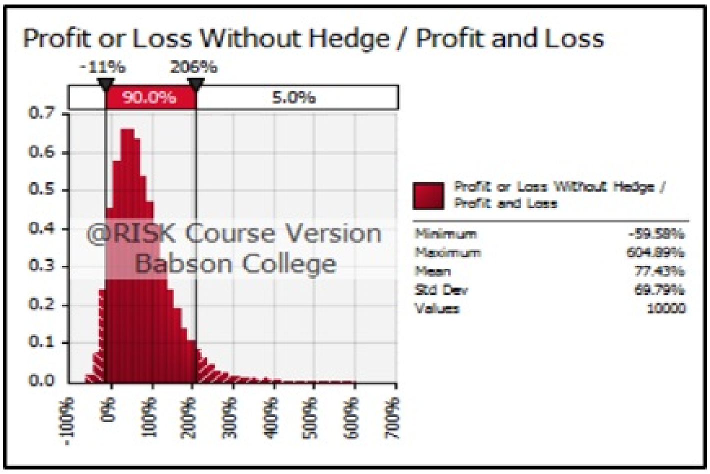

Figure 5: Simulated P&L percentages of unhedged portfolio in upward trend.

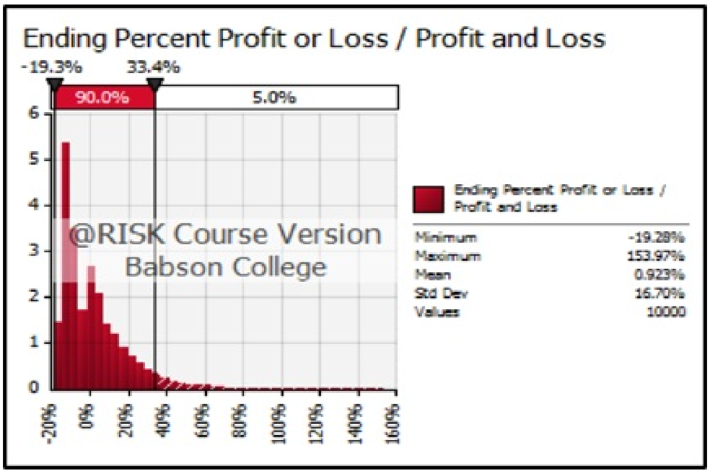

Figure 6: Simulated P&L percentages of strategy with a neutral price trend.

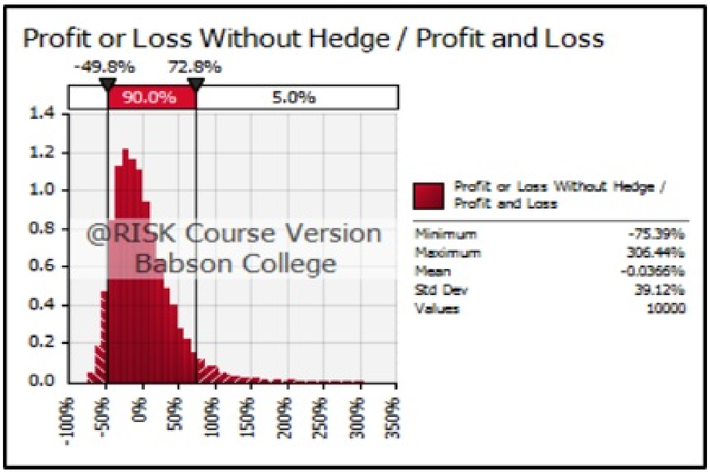

Figure 7: Simulated P&L percentages of unhedged portfolio in neutral trend.

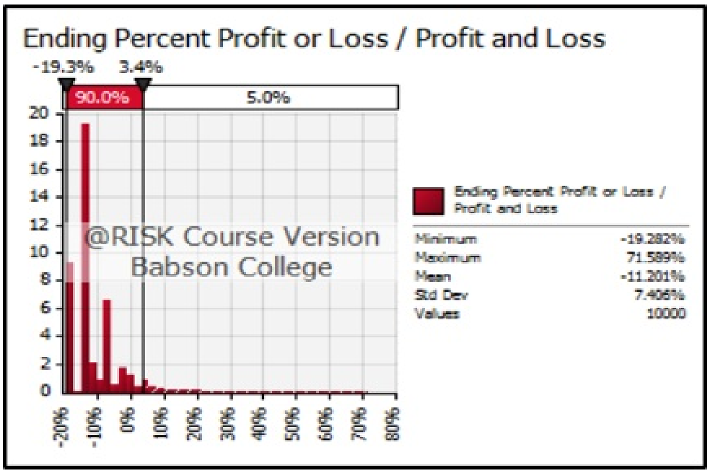

Figure 8: Simulated P&L percentages of strategy with a negative price trend.

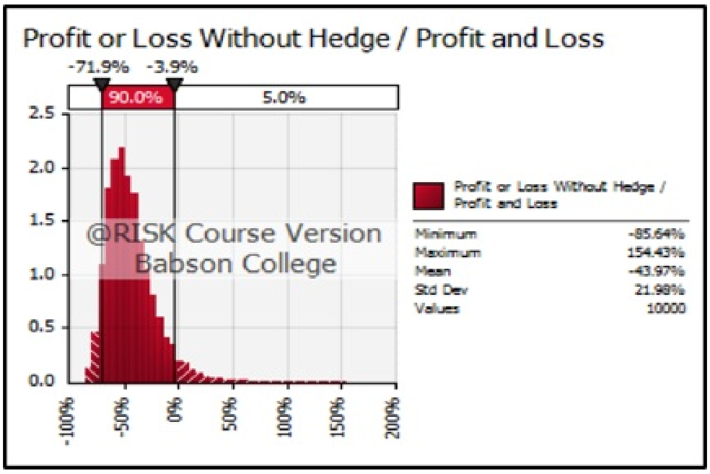

Figure 9: Simulated P&L percentages of unhedged portfolio in a downtrend.

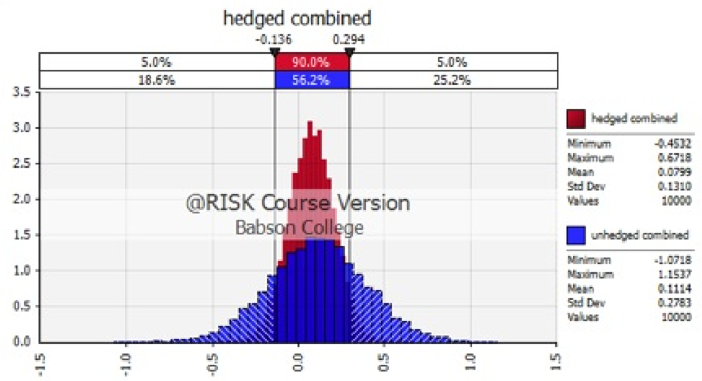

Figure 10: Combined P&L percentages each scenario, hedged and unhedged.

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